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WADC TECHNICAL REPORT 52-331

STANDARDIZED CALIBRATING FLUIDS

CECIL B. SHEPHERD, JR., 1ST LT, USAF
POWER PLANT LABORATORY

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Statement A
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SEO No. 533-109A

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report was prepared by the Engine Accessories Branch under SEO No. 533-109, "Fuel Metering Systems." The report covers the sub-project entitled, "Standardized Calibrating Fluids." The Air Force phases of the program were administered under the direction of the Power Plant Laboratory, Directorate of Laboratories, Wright Air Development Center, with 1/Lt. C. B. Shepherd, Jr. acting as project engineer. This report is being written to present an overall review of the action leading to the adoption of standard calibrating fluids to be used in the testing and calibration of all fuel metering equipment utilized in reciprocating and jet aircraft engines and to recommend that the sub-project be closed out as a result of the completion of the project.

A large group of individuals from the Power Plant Laboratory and other groups both under the Wright Air Development Center and the Air Materiel Command (Wright-Patterson AF Base), the Aeronautical Standards Group, the Munitions Board, the Bureau of Aeronautics, and industry and the Aircraft Industries Association were involved in this program. Of special note, in respect to the more current Air Force activities involved, is the cooperation of Mr. C. T. Bedell, Power Plant Laboratory, in the engineering of the project.

ABSTRACT

The standardized calibrating fluid project was initiated for the purpose of investigating available calibrating fluids and standardizing on one or more of these fluids for the calibration of all military aircraft fuel metering components. After a lengthy series of fluid investigations and conferences, involving the Air Force, the Navy and appropriate sections of the aircraft and component industries, an agreement on the fluids to be used was reached. The project work has been concluded with the agreement on the provisions to be placed in the Specification MIL-F-7024A, specifying normal heptane as the calibrating fluid to be used for all reciprocating engine fuel metering components and a special fluid for all jet engine fuel metering components.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:


NORMAN C. APPOLD

Colonel, USAF
Chief, Power Plant Laboratory
Directorate of Laboratories

I. INTRODUCTION

During the middle and late nineteen-forties, it became more and more evident that the existence of a large number of calibrating fluids for fuel metering elements constituted an undesirable condition. Correlations between two groups running flow tests on the same units were often unsatisfactory. At times rejection rate increases could be charged to such lack of correlation. An added burden was placed on any central agency through additional storage and handling requirements. Some of the fluids utilized exhibited harmful properties from the standpoint of storage effects on rubber. It was felt that fluids exhibiting such properties were not fully satisfactory for calibration purposes.

The above factors were recognized nearly simultaneously by the Air Force, the Navy and the segments of the aircraft industry involved. The report that follows discusses the various activities leading up to a specification directing the use of normal heptane as the calibrating fluid for all reciprocating fuel metering elements and a special fluid for all jet engine elements.

II. GENERAL DISCUSSION

While the expenditure order for the project under discussion dates from June 1951, the action involved actually dates back to the fall of 1949. In 1949 a series of fluid evaluation programs and conferences were started, involving the Air Force, the Navy and the aircraft and fuel metering component industries. The Bureau of Aeronautics (Navy) with the assistance of the Bureau of Standards evaluated the various fluid possibilities and their effect on individual fuel metering elements. The Air Force, in turn, conducted from time to time investigations into the suitability of various possible test fluids, attempting to gain a picture on the comparative correlation between fluids. Industry, under the leadership of the Aircraft Industries Association, checked into fluid possibilities from the standpoint of the needs of its members. The use of various fluids was generally checked from the standpoint of reproducibility of properties, safety, toxicity, availability, strategic importance, effect on working parts, cost, stability, etc. Conferences were arranged to discuss the merits of the fluids. The conferences soon showed that in general industry was in favor of a Stoddard solvent type of fluid to be adopted as a standard. The Navy, largely seconded by the Air Force, after some indecision, felt that normal heptane should be chosen. A virtual deadlock developed which existed up to January 1952.

To gain an insight into the situation existing up to January 1952, it is important to examine some of the more important reasons effecting individual viewpoints of the parties involved. As previously mentioned, the Navy, with the aid of the Bureau of Standards, investigated a number of possible calibrating fluids. Navy personnel were impressed by the constancy of properties of the normal paraffins such as paraffin standard, iso-octane, decane and heptane. Although not the best from a property standpoint, heptane was felt to be the most promising fluid from an availability and cost standpoint. The selection of heptane fitted in very well with the Navy's preferential operating fluid, gasoline, as the density and viscosity properties were quite similar. All in all, heptane appeared the best available fluid to the Navy, so its use was vigorously pushed.

The jet engine industry, along with a number of suppliers of fuel metering equipment, investigated the fluid possibilities and decided in favor of a Stoddard solvent type of fluid. This fluid was inviting as it was cheap, had properties fairly closely resembling those of jet fuels, and was safe to operate with. Many manufacturer's testing facilities are not explosion proof, necessitating extensive revision of existing facilities for the use of a fluid such as heptane. Both expediencies and insurance laws dictated such action. In addition, some manufacturers were concerned about the possible toxicity of heptane. Comparatively little was heard from the reciprocating engine industry although generally a preference for continued use of naphtha was proclaimed, largely due to the extensive carburetor calibration data in existence and the difficulties involved in a changeover.

The Air Force did not adopt and maintain a consistent choice of calibrating fluids. Late in 1949, the Air Force professed willingness to go along with heptane except for carburetors. It was felt that too much data had been compiled on carburetors flowed with naphtha to change fluids on this component. In June 1950, the Air Force proposed the use of aliphatic naphtha for carburetors and modified AMS specification for aircraft turbine and jet control calibration, in a meeting with the Navy and the Aeronautical Standards Group. In a following meeting in August 1950, however, the Air Force agreed to back heptane along with the Navy, unless further testing proved heptane unsatisfactory. This decision on the part of the Air Force was for the purpose of holding the number of fluids down to one and due to the constancy of properties of the heptane.

With the decision by the Air Force and the Navy to standardize on normal heptane, action was taken by both services to obtain industrial cooperation in the adoption of this fluid. As a more positive approach, information as to the services decision to use heptane as the calibrating fluid along with dates for the establishing of limits was sent to Air

Force contractors in the summer of 1951. The replies received and the slowness of industrial action made it apparent that little was being accomplished towards the standardization goal. Meetings during the fall of 1951 involving the Air Force, the Navy and the Allison Engine Division of the General Motors Corporation brought out how deeply some segments of the jet engine industry were opposed to the use of heptane for calibrating jet engine fuel metering components and the reasonableness of their position.

Late in January 1952 a meeting was held in Washington involving representatives from the Air Force, Navy and Industry. As discussed at a meeting preceding the general meeting, the Services presented a compromise solution to the Aeronautical Industries Association and representatives from appropriate manufacturing concerns. The solution presented called for the use of heptane as the calibrating fluid for all reciprocating engine fuel metering components and a closely controlled cut from the Stoddard solvent band for the jet engine components. Industry was agreeable.

The aftermath of the decision on the use of the standard calibrating fluids resulted in the requirement for a specification, to be designated as MIL-F-7024A. The Air Force prepared the original draft and after internal coordination, sent it through the Aeronautical Standards Group to the Bureau of Aeronautics.

During the period which the Air Force was writing and circulating a preliminary draft of the specification, the Navy was investigating samples, submitted by various oil companies, for properties to parallel those required for the jet engine test fluid. Most of this activity centered around the investigation of rubber swell factors, in fuel metering elements, and the definition of an acceptable rubber swell index. This work required a somewhat longer period than the original drafting of the proposed specification and, consequently, delayed the program somewhat.

On 6 August 1952 a meeting was called by the Aeronautical Standards Group for the purpose of defining the final specification requirements. The Aeronautical Standards Group, Air Force, Bureau of Aeronautics and Industrial representatives participated in the meeting. The results of the rubber swell tests and sample jet engine fluids were presented by the Navy. The final specification was to contain essentially the provisions of the Air Force draft with the substitution of a requirement for an aniline point-rubber swell index test for a stated maximum aromatic content, plus some minor revisions in fluid property requirements. The Aeronautical Standards Group was to write the final specification draft.

III. CONCLUSIONS AND RECOMMENDATIONS

The program to standardize on calibrating fluids to be used in fuel metering element tests has been successfully concluded. The decision has been made to utilize normal heptane for reciprocating engine components and a special fluid for jet engine fuel metering components. The specification designated as MIL-F-7024A will cover the requirements in respect to these two fluids. With universal adoption of this specification by the Air Force, the Navy and appropriate engine and accessory manufacturers, improved correlations should be obtainable along with major savings due to stocking and handling requirements for fewer fluids, longer storage life for rubber parts and a lower rejection rate on fuel metering elements.

When the specification is available in final published form, covering the two standard calibrating fluids, the requirement for universal use of the fluids in appropriate fuel metering element calibration should be placed in both general engine specifications and individual procurement contracts, as appropriate. All Military agencies involved and all appropriate manufacturers, suppliers and users of fuel metering equipment, within the scope covered, must be notified of the fluid requirements and furnished with copies of the Specification MIL-F-7024A.

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APPENDIX I

FLUIDS, CALIBRATING, FOR AIRCRAFT FUEL SYSTEM COMPONENTS

1. The following requirements have been specified for test fluids for use in the calibration of fuel system components for aircraft reciprocating engines and aircraft gas turbines. The Type 1 test fluid requirements cover the normal heptane (commercial grade) to be used for all reciprocating engine components. The Type 2 test fluid requirements cover the special fluid, similar to a closely controlled Stoddard solvent, to be used for all jet engine components. The requirements, as listed, are the same as those to be specified in MIL-F-7024A.

2. Type 1 Fluid Requirements.-

a. Specific Gravity.- The specific gravity of the calibrating fluid shall not be less than .697 nor more than .701 at 15.6°C/15.6°C (60°F/60°F).

b. Color.- The color of the fluid shall not be darker than +25 (Saybolt Chromometer).

c. Corrosion (Copper Strip).- The fluid shall be reported as passing when no visible difference exists between the exposed strip and a freshly polished copper strip when tested as specified in Section 4.

d. Viscosity.- The viscosity of the fluid shall be 0.785 ± 0.01 centistokes at 0°C (32°F), and 0.540 ± 0.01 centistokes at 37.8°C (100°F).

e. Reid Vapor Pressure.- The Reid Vapor Pressure at 100°F shall be 2.0 psi maximum.

f. Residual Gum.- The residual gum content of the finished fluid shall not be greater than 2.0 milligrams per 100 milliliters.

g. Accelerated Gum.- The accelerated gum content of the finished fluid shall not be greater than 5.0 milligrams per 100 milliliters after a 5-hour aging period.

h. Distillation Range.- The distillation range of the fluid between the 5 percent and 95 percent points shall not exceed 3°F and shall include the temperature 208°F.

3. Type 2 Fluid Requirements.-

a. Specific Gravity.- The specific gravity of the calibrating fluid shall be 0.770 ± 0.005 at 15.6°C/15.6°C (60°F/60°F).

b. Corrosion (Copper Strip).-- The fluid shall be reported as passing when no visible difference exists between the exposed strip and a freshly polished copper strip when tested as specified in Section 4.

c. Viscosity.-- The viscosity of the fluid shall be 1.12 - 1.22 centistokes at 77°F.

d. Distillation Range.-- The distillation range of the fluid shall be as follows:

| | |
|-----------------------|------------|
| Initial Boiling Point | 300°F |
| Final Boiling Point | 410°F |
| Recovery | 98.5% Min. |

e. Flash Point.-- The flash point of the fluid shall not be lower than 100°F.

f. Aniline Point and Rubber Swell Index.-- The aniline point of the fluid shall be 150°F or greater, except, if the fluid exhibits a rubber swell index of 45 or less, it will be deemed acceptable. For all samples, the aniline point must be first determined.

g. Bromine Number.-- The bromine number of the fluid shall not exceed 3.

h. Residue.-- The residue after evaporation by the air jet method shall not be greater than 10mg per 100 milliliters of fluid.

i. Neutrality.-- The residue from distillation of the fluid shall have no acid reaction to methyl orange.

j. Mercaptan Sulfur.-- The mercaptan sulfur content of the fuel shall not exceed 0.005 percent by weight. The mercaptan sulfur determination may be waived at the option of the Inspector if the fuel is considered "sweet" when tested in accordance with Method 520.3 (Doctor Test) of Specification VV-L-791.